

Cloud computing for radiologists

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Abstract

Cloud computing is a concept wherein a computer grid is created using the Internet with the sole purpose of utilizing shared resources such as computer software, hardware, on a pay-per-use model. Using Cloud computing, radiology users can efficiently manage multimodality imaging units by using the latest software and hardware without paying huge upfront costs. Cloud computing systems usually work on public, private, hybrid, or community models. Using the various components of a Cloud, such as applications, client, infrastructure, storage, services, and processing power, Cloud computing can help imaging units rapidly scale and descale operations and avoid huge spending on maintenance of costly applications and storage. Cloud computing allows flexibility in imaging. It sets free radiology from the confines of a hospital and creates a virtual mobile office. The downsides to Cloud computing involve security and privacy issues which need to be addressed to ensure the success of Cloud computing in the future.

Key words: Cloud computing; PACS; radiology; RIS; teleradiology

History of Cloud Computing

The concept of Cloud computing was introduced in the 1960s by J C R Licklider,^[1] although he did not use the term “Cloud” but called it an interconnected grid of computers. References also exist suggesting that John McCarthy, known for his work on artificial intelligence, discussed the concept of using computing for public use.^[1] The momentum for Cloud computing developed in the late 1990s due to improvement in hardware, software, easy availability of telephony and high bandwidth Internet.

What is Cloud Computing?

Cloud computing uses various software, data access, and data storage services that do not demand end-user knowledge of actual physical location and arrangement of services.^[2]

Cloud computing in simpler terms also means the concept of using an interconnected grid of computers allowing sharing of resources and using the Internet as a medium and working on a pay-per-use model.

Cloud computing in radiology is not simply a web-based image sharing platform, but also includes web-based Radiology Information System (RIS) modules. RIS modules can be a part of web-based Electronic Health Record (EHR) modules.

What are the Components of Cloud Computing?

The following are the components of the Cloud:^[3]

- Application:** This is the major component of the Cloud, which radiologists as “end users” utilize. This is known as “Software as a Service.” Examples are image reviewing, reporting software, or radiology billing software.
- Client:** Client refers to the web browser. It is the medium which end users use to access the Cloud via the Internet. This can be a computer or a smartphone.
- Infrastructure:** This consists of computer hardware and servers which run the software and store data.
- Service:** This is the actual benefit the end users derive from Cloud. A service can be either web-based Picture

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- Archiving and Communication System (PACS) or web-based film library.
- Storage: This is an important feature of Cloud computing. Entire database of cases and years of data can be stored in the form of documents and DICOM image libraries. In contrast, physical storage at site (hospital or imaging center) is expensive and difficult to maintain.
 - Processing power: Cloud has the potential of providing infinite processing power at a very low cost.

The various components of a typical Cloud system are illustrated in Figure 1.

How is Cloud Computing Classified?

Cloud computing is classified into four types on the basis of the location of hosting a Cloud. They are public, private, hybrid, and community Clouds.^[4] An illustration of various types of Cloud is given in Figure 2 and Table 1.

- Public Clouds are for general use and the hosting is done by the vendors.
- Private Clouds are strictly for in-hospital use and are more secure as they deal with confidential patient data. Hosting is at the vendor or the hospital premise.

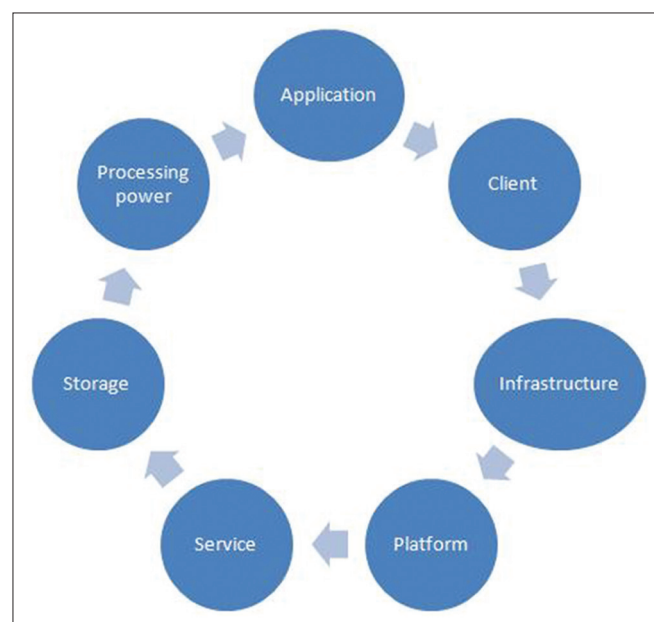


Figure 1: Components of cloud computing

- Hybrid Clouds allow noncritical information hosting on public Clouds and critical/confidential information in the private domain.
- Community Clouds allow information to be shared by the same community. Few hospitals/imaging centers can team up in a Cloud while sharing similar infrastructure and software.

Impact of Cloud Computing on Radiology Workflow

- Knowledge of IT: At present, radiologists in imaging departments (end users) have total control over its IT infrastructure by purchasing and balancing them as per their need. In contrast, Cloud computing allows end users to use these IT-related services without knowledge or control over the infrastructure that supports and maintains it.^[6]
 - Costing: Cloud computing allows radiology end users to use costly hardware and software stored remotely over the Cloud-based systems. There is no requirement of purchasing them by paying upfront costs, but rather use the pay-per-use model.
- In Cloud computing, various radiology and medical applications are delivered as a service over the Internet and

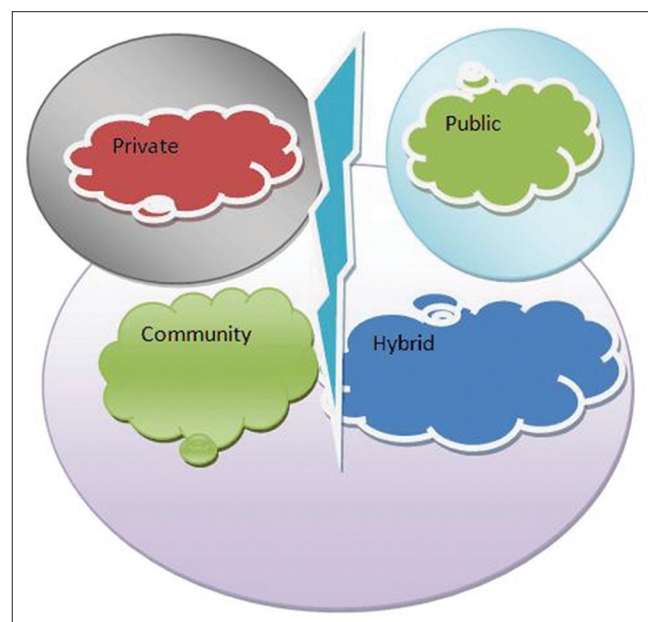


Figure 2: Types of clouds

Table 1: Types of cloud computing systems for radiology

Types	Cloud components	Advantages	Disadvantages
Public	Radiology software as a service (RsaaS)	Flexible and scalable	Data security
Private	Radiology/imaging infrastructure as a service	Rapid deployment in urgency	Privacy
Community	Platform as a service	Pay per use	Unforeseen service failures (server down!)
Mixed	Open source based service	Reduced capital costs	Limited inter-cloud operator portability
		Increase system efficiency ^[5]	Viruses and bugs

this is known as a software as a service (SaaS)/on-demand software.^[7]

- c. Integration: A Cloud-based system provides a software platform for RIS, PACS, remote image review software (teleradiology), advanced 3D workstation software, and billing software, and this is actively accessed by end users remotely by using computers or tablets over the Internet.

How does Cloud Computing Benefit the Radiology Department?

Cloud computing allows administrators of radiology departments dynamic upscaling and downscaling operations without the burden of maintaining software and hardware. This makes imaging truly virtual. Radiologists need not maintain many IT products like software and hardware, but simply have a single central processing unit.^[8] This system allows radiologists to focus on their practice and not how or where the service is processed, hosted, or routed.^[3] A typical Cloud computing based radiology unit flowchart is shown in Figure 3.

Few Cases Illustrating the Role of Cloud Computing in Radiology

An imaging unit A had purchased a server to store DICOM images and pertinent patient information. The imaging unit had no earlier experience in the upkeep of the server. The server crashed and the data was lost. Aggrieved by data loss, and also constant upgrades and space constraints, the imaging unit shifted their data to the Cloud. By doing this, the end users saved on server software/hardware, maintenance costs, and licenses. In this scenario, the Cloud functioned as a PACS, RIS, teleradiology software, and billing unit.

Hospital B has an imaging department that had a requirement of a system wherein images are available

online and can permit all radiologists to report remotely from outside the hospital. They tried using the hospital server and PACS, but due to Internet issues and frequent LAN disruptions within the hospital network, it was a tough user experience. Opting for the Cloud, the radiologists can now access web-based radiology software and check the images using available broadband. Here, the Cloud acts as a teleradiology unit.

Hospital C does not have an RIS and they are aware of a company that possesses a Cloud-based RIS. The hospital wants to start utilizing the system as they have a short time frame to digitize the radiology information record system. Instead of searching for an ideal RIS, and then customizing it to hospital settings, followed by launching and maintaining the hardware/software on each of their systems, they simply opt for a Cloud-based system. The hospital can train the staff and launch the application within a short notice. Here, the Cloud stores the RIS. Using a community Cloud, many hospitals can share standard software and be integrated and save the cost.

Hospital D has opened an imaging center in a remote location. They need to push images in real time from the center to radiologists at a nodal center and report the same. Instead of investing in new hardware and software at the remote unit, they push the images into the Cloud, enabling the radiologist to review images at nodal center, thereby avoiding duplication of software and hardware. In this example, the Cloud acts as a gateway to the peripheral center wherein all its information is available on the Cloud.

Hospital E has procured costly, state-of-the-art software that allows for real-time 3D and 4D reconstructions from CT scan and USG images. Purchasing the same for 20-30 imaging centers run by the hospital chain would amount to significant cost escalation. By opting for a Cloud-based system, the hospital gets the unique flexibility of a pay-per-use option and all CT scans get real-time 3D and 4D expertise. This illustrates the benefit of storage and transmission in the Cloud and running 3D/4D software applications.

Hospital F has several physicians advising scans of patients who finally get operated/treated in other hospitals. Surgeon F requests for the CD of a patient before performing the surgery. Unfortunately, the CD is not compatible with software on the surgeon's computer. Surgeon F requests the radiology administrator to enable access to the Cloud-based system, using which the physician reviews the images on his tablet by logging in using a secure ID and password. He is now able to plan the surgery and discuss findings with the patient and the relatives. As exemplified by this case, the trend of using hybrid/public Clouds for managing cases at the bedside and at point of care is growing.

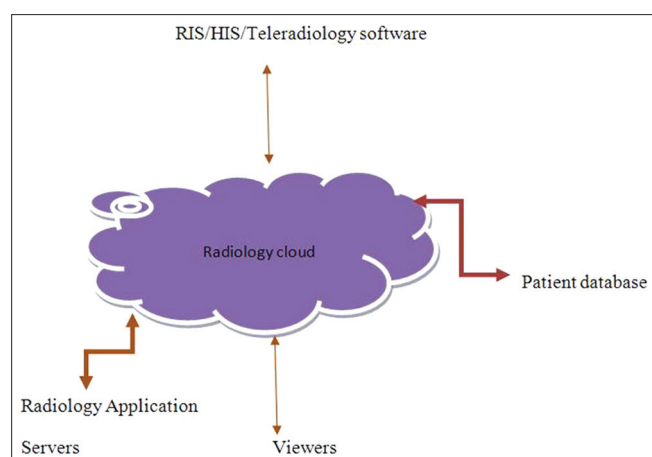


Figure 3: Typical radiology Cloud

Patient G performs a positron emission tomography (PET)/CT for a metastatic lung carcinoma at a center G, and after 6 months, the patient relocates to another city where he undergoes a follow-up CT scan. The patient provides the reporting radiologists direct access to images stored on a hybrid Cloud. The radiologists retrieve and merge the images on their workstation. Using a suitable hanging protocol, the radiologist reviews and reports the comparison scans. This case demonstrates the impact of a hybrid Cloud and issues of access by a knowledgeable patient.

The impact of Cloud computing in radiology is summarized in the Table 2.

Advantages of Cloud Computing in Radiology

Knowledge about the working of Cloud systems is extremely essential to help a radiology administrator make informed and intelligent decisions. Radiologists in departments and clinics can benefit from the Cloud by tailoring it in the following ways:

- Store data
- Boost productivity
- New software and extra storage available as and when required
- Access patient data, billing, insurance, reports outside the hospital
- Academic institutions can archive studies, maintain directories, and conduct exams
- Teleradiology companies can maintain access control, manage billing, and keep audit trail
- Radiologists and physicians can use data instantly when a new exam lists on the PACS
- Decreased costs on infrastructure due to a pay-per-use model
- System maintenance, performance, and security managed by professional agencies

Shortcomings in Cloud Computing

In Cloud computing, protected patient data is stored remotely in virtual compartments in the storage media. The protected patient information is sent and received to and from the server through the Internet. This makes the data vulnerable to security breach. The list below mentions the threats Cloud computing faces, with solutions to overcome potential threats:

- New challenges in data security and privacy:^[9] This problem can be minimized by data encryption during storage and transfer and connecting with the server using a secure URL such as those URLs beginning with https (s stands for secure).
- Close audit trail, biometric checks mandatory to allow controlled access.
- Database safety and long-term archival process needs to be discussed with the Cloud computing service provider in case of emergencies and natural disasters.
- Server failure may disrupt services. This can be avoided by maintaining mirror servers.
- Efficiency of service is related to broadband speed. The hospital may need to tie up with multiple Internet service providers to prevent disruption of service.

Future of Cloud Computing

As per the study conducted by an expert group, exploring the future for European Cloud computing beyond 2010, it has been noted that Cloud computing has not yet been completely exploited and its true potential has not yet been achieved.^[10]

The main goal of Cloud computing will be to address concerns regarding safety and privacy of data before there is large-scale shift of health care and imaging data into Cloud-based models.

Table 2: Few examples of impact of Cloud computing systems in radiology

Example	Location	Workflow in radiology	Problem	Solution	Role of Cloud
A	Unit A	Store image and non-image data	Frequent server crash	Shift data to Cloud	Multiple roles as PACS, RIS, teleradiology, billing unit
B	Hospital B	Remote reporting by radiologists	Poor hospital network and LAN infrastructure	Opt for Cloud	Facilitates teleradiology with no extra software
C	Hospital C	Digitizing Radiology Information System	Searching and customizing an optimal RIS	Move to Cloud	Stores RIS and integrates the software
D	Hospital D	Receiving and reporting from remote imaging center	Investment costs in new hardware/software at remote center	Push images into Cloud	Acts as a gateway to peripheral center
E	Hospital E	Purchasing costly software for real-time 3D and 4D CT and USG reconstructions	Cost	Opt for a Cloud system	Stores, transmits, and runs 3D/4D software applications
F	Hospital F	Pre-op analysis of CD	Incompatible software	Access to Cloud-based system	Manage cases at bedside/at point of care
G	Patient G	Follow-up CT for cancer	Different machine, dates, and city	Access to images stored on hybrid Cloud	Impact of hybrid Cloud

In the distant future, the radiology departments will witness a large-scale migration to Cloud-based PACS and RIS due to easy availability and low upfront costs.

Conclusion

In a nutshell, Cloud computing promotes the concept of “round-the-clock” radiology, bedside radiology, point-of-care radiology, and instant radiology. It gives the radiologists, physicians, and even patients the ability to review images on any display device with an Internet connection.^[11] Cloud computing inserts flexibility which is necessary in a highly competitive and costly radiology practice. Cloud computing has the potential to transform a digital imaging practice and can further revolutionize the way we store, access, and process our radiology data.

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